PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERIZATION OF BIOFILTERS FOR THE TREATMENT OF GAS EMISSIONS IN INDUSTRIAL PLANTS

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1 INTRODUCTION

The purpose of a biofilter is the purification of biological contaminants such as fungi, bacteria, enteric viruses, and endotoxins contained in the air of industrial plants that treat wastes, such us Municipal Solid Waste, ranching wastes or sludge of Waste Water Treatment Plant. Secondly, this auxiliary system of treatment of air, removals of most odor-producing compounds with a capacity of purification that in some cases can be higher than 95%.

The aim of this work was to determine the variables that most affect the proper functioning of biological filters used to purify air from waste treatment plants. To this biofilters converges air from the composting tunnels (closed reactors with the addition of air to accelerate the process of respiration) and the air extracted from the discharge area in order to preserve the health of workers. This is a research line with little background information. The variables have been characterized for two biofilters with different types of porous filler: a green biofilter, using wood chips from timber wastes (genus *Populus*) and a OFMSW biofilter, using Organic Fraction from Municipal Solid Waste partially stabilized.

The biofilters structure included a gravel layer at the bottom, which favors the spread of polluted air, in both cases. On this gravel, a layer of organic material was deposited, leaving a large void volume which allows the air passing through without a great loss of pressure. Moreover, the biofilter must be dimensioned in order to enable an adequate residence time to treat the ventilated air. There are special cases, where biofilters used for agricultural wastes with an empty bed residence time (EBRT), of just 5 seconds, while other applications treating air at concentrations of 1000 ppm H_2S require 50-60 seconds for attaining a removal efficiency of 90%. As a general rule, Haug (1993) found that the odor treatment for MSW composting plants requires EBRT between 30-60 seconds. As a biofilter is essentially a filled container which has the principal resistance offered by the media, it is not expensive or difficult to build.

2 MATERIALS AND METHODS

The term EBRT is calculated as the empty biofilter volume divided by the volume air flow. Typical EBRT values quoted in the literature vary depending on the characteristics of the gas to be treated. Experimental EBRT values are generally used to design the biofilter for the treatment of a contaminated gas flow for a specific pollutant (Devinny et al. 1999).

$$EBRT = \frac{V_f}{Q}$$

where EBRT is the time empty bed residence (h^{-1}), Vf = filter bed empty volume (m^3) and Q = air flow to be treated ($m^3 \cdot h^{-1}$). Leson and Winer (1991) reported that the treatment of odour emissions generated in industrial and commercial requires no less than 25 seconds of EBRT. This minimal value is typically used for the design of fixed bed biofilters.

In addition, the following physical determinations, for assessment and comparison of biofilters quality, have been made: porosity of the packing material, (calculated by the volumetric method of adding water), its particle size distribution (mesh size of 3, 5 and 10 mm) and the characterization of the called organic fraction of MSW, understood this, the ultimate elements that constitute the filling. So as being OFMSW a heterogeneous material partially stabilized, were selected manually fractions as glass, paper, plastic and other items to know its proportion in the filler and the amount of inert materials.

The chemical monitoring and characterization of the two raw materials (MSW compost and green wastes) was carried out by measuring organic matter (% VS), moisture (%) and pH, according to the Standard Methods (APHA, 1989). Finally, the biological evaluation was developed by the horizontal method of counting total aerobic bacteria, yeasts and moulds at 30° C.

3 RESULTS AND DISCUSSION

An EBRT value of 0.011 hours (40 seconds) was obtained from a green biofilter, volume of 275 m^3, treating the air of a composting plant with 8 tunnels working with an intake flow air of 3125 m^3/h. In contrast, another EBRT value of 0.051 hours (183 seconds) was obtained from the OFMSW biofilter, volume of 273,3 m^3, in a composting plant with 4 tunnels working with an intake flow air of 1340 m^3/h.

These EBRT values far exceed the recommended values found in literature for most of the odour products that are produced during composting. It should be mentioned that the residence time (EBRT) overestimates the actual time of treatment since it does not consider the porosity of the filter, which will decrease the contact time between the gas phase and solid phase (Devinny et al. 1999). Therefore the real residence time is defined as the total filter bed volume multiplied by the porosity of the bed of the filter medium and divided by the air flow to be treated.

$$\tau_r = \frac{V_f \cdot \theta}{Q}$$

where τr = Real residence time (s), Vf = Filter bed empty volume (m^3), θ = P Porosity or volume of voids/volume of bed (dimensionless) and Q= Volume of flow treated ($m^3 \cdot s^{-1}$).

Soil porosity is represented by the percentage of existing gaps and is usually empirically determined. Macroporosity, or no capillary porosity is formed by large gaps. The limit between macro and microporosity is fixed between 8 and 10 μm corresponds to the limit of the water holding capacity, where it is on hold with such force that it is not capable of vertical displacement by gravity, so these pores, once filled with water, always remain, unless some outside force is applied to the shift. The analysis of the material porosity showed a total value of 91% for the green biofilter (53% microporosity and 38% macroporosity) and 79% for OFMSW biofilter (70% microporosity and 9% macroporosity). This analysis suggests that circulation of air is favoured in green biofilter versus OFMSW biofilter being the porosity total in this case appropriate too.

Considering the necessary correction, τ_r reached a value of 36 seconds for the first case and 145 seconds for the second case. These results indicate that the OFMSW biofilter was oversized.

Particle size and organic matter content of the packing media are very important variables to be considered for the appropriate biofilter operation. Whilst a large 10 mm + fraction is not desirable for the agricultural application of compost product is desirable in a biofilter, in order to increase the porosity for air circulation. Granulometric analysis (Table 1) revealed that particle size distribution is very different in both biofilters. More, in the OFMSW biofilter the fraction with a particle size lower than 3 mm (49.9%) coincide with the organic matter reported in OFMSW biofilter characterization (50.4% organic matter, 28.1% glass, 5.5% paper, 3.2% plastic and 12.9% others).

TABLE 1 **Size particle fractions of the media used in the two biofilters (% dry weight)**

	Green Biofilter	**OFMSW Biofilter**
Over 10 mm	49.4	27.1
Between 5 and 10 mm.	26.4	17.0
Between 3 and 5 mm.	15.9	6.0
Less than 3 mm.	8.3	49.9

Moisture and organic matter (Table 2) were analyzed at different depths, showing stratification in both cases. In relation to moisture, there is an analogy between the two biofilters. It should be noted that the green biofilter has much higher moisture, causing a washing of microorganisms present in micropores. This fact suggests that in some cases would require the covering of this installation, in order to maintain permanent moisture conditions throughout the year. Conversely, in the case of OFMSW biofilter, the moisture in the media is considered too low to provide conditions for optimal biomass development. The optimum moisture range for the operation of the biofilter is between 40 and 60%. The maintenance of this desired level is a critical variable for the correct biofilters operation (Warren et al., 1997). In relation to organic matter content, it increases in depth.

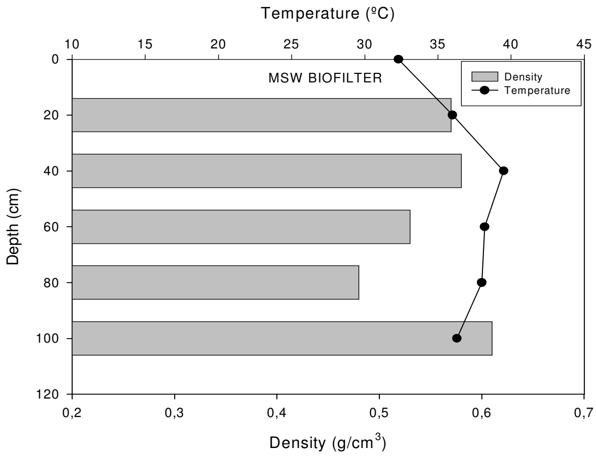
TABLE 2 **Moisture and organic matter content**

	Moisture (%)		Organic Matter (% d.w.)	
Depth (cm.)	**Green Biofilter**	**OFMSW Biofilter**	**Green Biofilter**	**OFMSW Biofilter**
0	82.0	5.2	86.8	12.2
20	92.6	16.8	93.8	18.4
40	93.7	15.6	91.1	14.3
60	98.5	18.5	93.1	27.2
80	96.0	20.9	97.1	30.8

Figure 1 show Density and Temperature of the media in each biofilter at different depths. As can be observed, the density of the material was fairly uniform implying a consistent porosity. Density varied in the range 0.22 - 0.33 g/cm^3 for green biofilter and 0.48 - 0.61 g/cm^3 for the media in the OFMSW biofilter. These results suggest that diffusion processes are not affected or even highly favoured in green biofilter, as the porosity is directly related to the volume of free holes through which air circulates.

On the other hand, temperature is a key variable for microbial growth. Microorganisms growing on biofilters filling are mesophiles, growing at temperatures in the range of 15 - 41° C. Therefore it is important to monitor periodically the temperature, as has been essential to monitor the humidity in order to avoid excessive moisture, causing the displacement of the microbiota present in the micropores by water.

The temperature in OFMSW biofilter varied from 32ºC to 40°C, thereby providing optimal conditions for the development of mesophilic microorganisms. The temperature profile shows that the warmest zone is located between 40 cm and 60 cm, being lower for green biofilter, where the high humidity causes the washing effect mentioned previously.



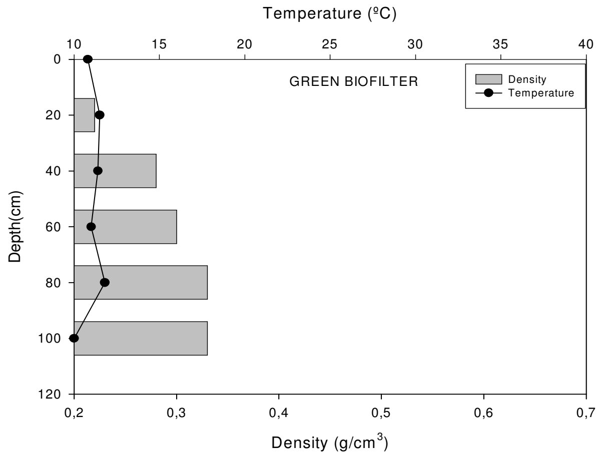


FIGURE 1 **Density and Temperature in both biofilters at different depth.**

Another interesting factor to be considered is pH, which was found to be 7.9 and 7.7 for the two biofilters studied, respectively. These values are close to that of the original media (8.5) at the application time. This fact suggests a great buffer capacity, making unnecessary the addition of carbonate or other buffering commodities frequently used, especially for H_2S purification or airs with acid compounds in its composition.

Finally, the total aerobic microbiological analysis of both fillings (Figure 2) reported the most interesting results. It has been determined total aerobic bacteria, yeasts and moulds at 30° C. The microbial concentration on the wood chip filling was much higher than in the material at the beginning of the operation of. this biofilter. In contrast, the aerobic microbial concentration in the OFMSW biofilter was lower than it was at the application time. Nevertheless, microbial concentration in this biofilter remained at higher values than in the green biofilter, particularly at the central zone (with values between 10^8 and 10^9 CFU/g d.m.), where the temperature and moisture conditions are the best. Thus suggesting that both types of fillers adapt to environmental conditions and that microbial colonization is high for green wastes.

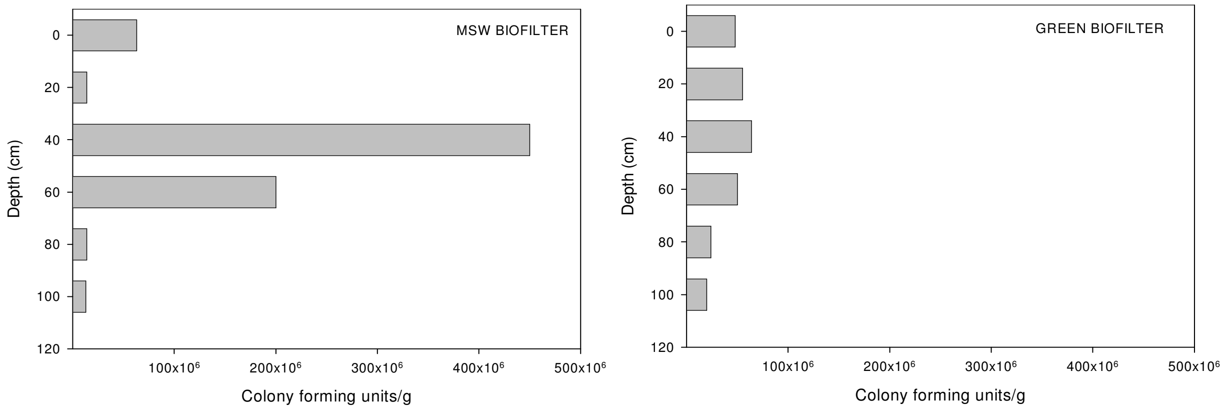


FIGURE 2 **Total aerobic bacteria, yeasts and moulds at 30° C.**

4 CONCLUSIONS

The use of a biofilter filled with OFMSW offers a number of drawbacks and advantages over the green biofilter. OFMSW partially stabilized used as biofilter is more advantageous than other organic fillers, because it contains microorganisms and nutrients which enables an optimum performance in a shorter time. Secondly, its biomass is very diverse and the likelihood of suitable bacteria for the purification of odours increases. However, the inconvenience of the lower life expectancy of this landfill media must be considered. Depending on the ventilation air to be treated, this ranges from 6 months to 2 years, while fillers based on wood chips (the most commonly used are of the genus Populus), can last from 4 to 7 years.

The air residence time, (expressed as empty bed residence time, EBRT), was several times higher than recommended in the literature for the purification of odours in industrial emissions (EBRT>25 seconds) in both cases. Organic matter, pH, particle size, density, and material characterization were not significant for determining microbial concentration. Moisture and temperature were the most crucial factors for the microbial distribution, while porosity (related to particle size) was essential for the appropriate biofilter operation.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Junta de Andalucía (Expte. 2062/2007/C/00) and the Ministry of Science and Innovation (Project: CTM2008-02714/TECNO) for funding this research. In addition, they thank the CONSORESTEPA composting plant in Estepa (Seville) and RESUR composting plant in Jaen for kindly supplying both material and human resources.

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